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Spherical Primary Optical Telescope (SPOT) Segment Fabrication

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NASA Goddard Space Flight Center

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Presented at Mirror Technology Days, Boulder, Colorado, USA, 7-9 June 2010.

14. ABSTRACT

The Spherical Primary Optical Telescope (SPOT) is a simplified large segmented telescope concept. At this time three, 35 inch diameter, hexagonal mirror blanks have been cast. The blanks are made of Pyrex. One mirror (segment) was figured at GSFC and final figured at QED using Magnetorheological Finishing. Two other segments are in process. The mirror tip, tilt, piston, and radius of curvature control assemblies are complete for Segment 1 and 2. Segment 2 was installed on a second generation support with enhanced stiffness and improved interfaces. Software is being written for the control assemblies. The test bed should be operational in Winter 2010.

15. SUBJECT TERMS

Spherical Primary Optical Telescope, Segmented, Mirror, Pyrex, Radius of Curvature, Casting, Deformable Mirror

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
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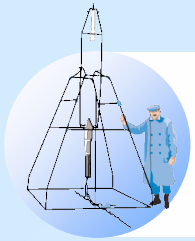

Spherical Primary Optical Telescope (SPOT) Segment Fabrication

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Joe Howard, Code 551
Scott Smith, Code 551
Matt Balcor, Code 551
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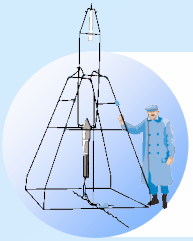
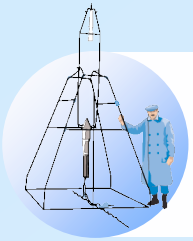


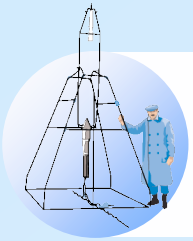
SPOT - 10x Cheaper Telescopes

- SPOT Architecture Simplifies Large Segmented Telescopes
  - Spheres are easier to make and test
  - Fewer degrees of freedom to control
- Real time WFSC with on-board star
  - Enables operation in more challenging environments (ISS)
  - Allows use of less exotic mirror materials
- SPOT mirror design enables real time ROC control
  - Mirror is cast with shape that decreases WFE induced by ROC change by 10 X
  - Casting of mirror decreases cost of segment blanks 15 X
- Spherical Primary Telescopes have decreased FOV
  - SPOT is best utilized for:
  - Planetary camera, LIDAR, Laser Comm

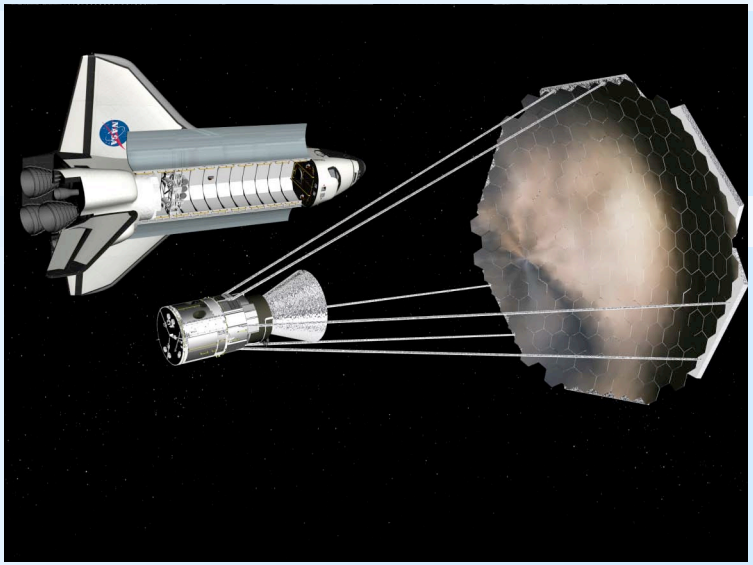


SPOT Testbed Status

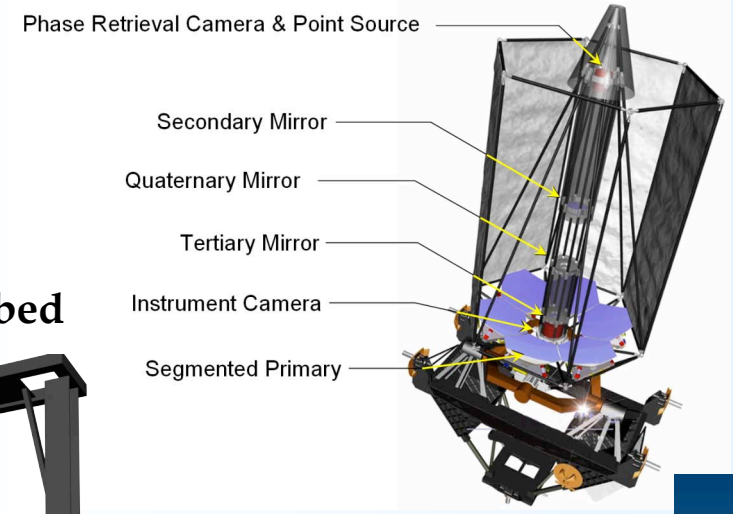
- 3 hexagonal mirror blanks (35″ point to point) have been cast
- Segment 1 was figured at GSFC completed at QED using magnetorheological finishing (MRF)
- New GSFC figuring facility brought on-line to complete initial figuring on segments 2 and 3
  - New machine can handle segments as large as 1 meter
- Segment 2 is in final figuring at QED
- Segment 3 is in figuring at GSFC
- Mirror tip/tilt piston and ROC control assemblies complete and software for control is being developed
- Test Bed should be operational this winter in Bld 7
- Modification of SPOT hardware for flight is evolutionary rather than revolutionary



SPOT Design Concepts

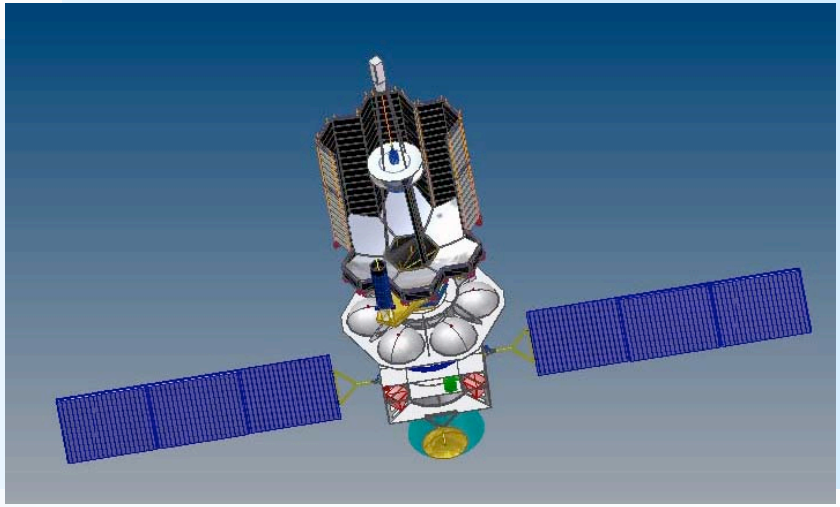


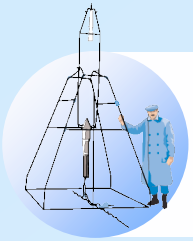
30 meter-Class SPOT



SPOT Testbed

SPOT ISS Attached Payload or Free-flyer

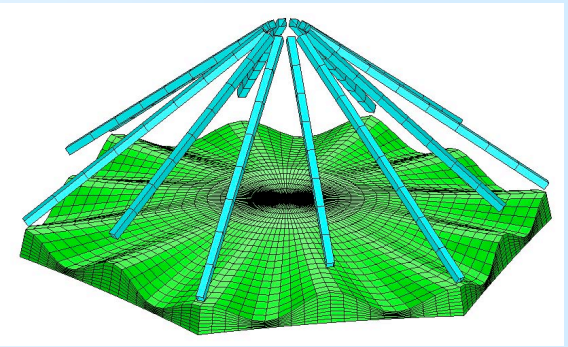


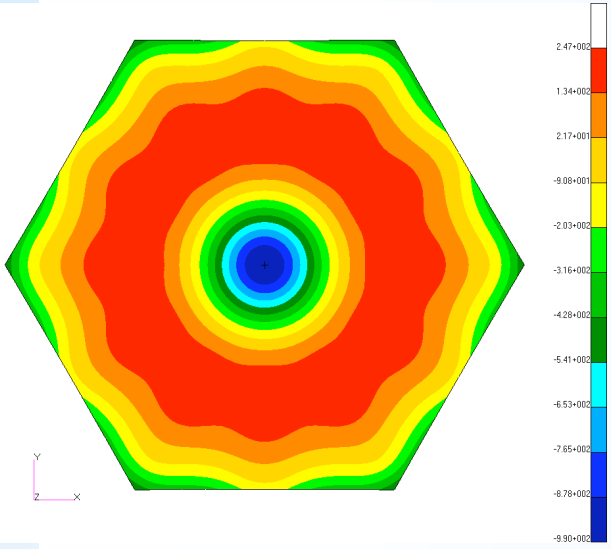


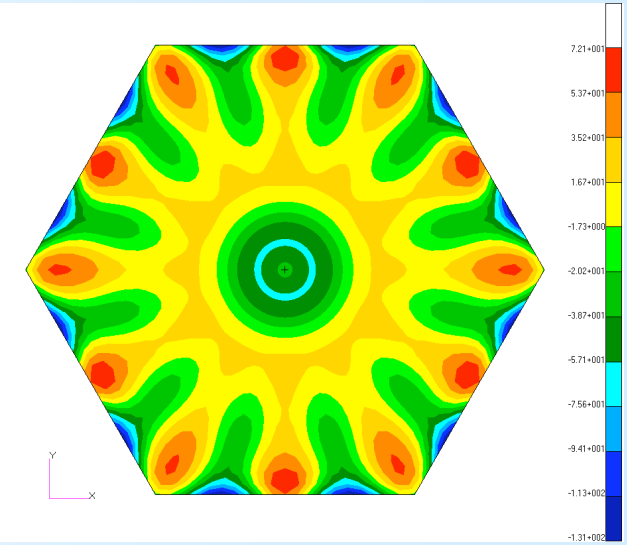
Accomplishments

SPOT Mirror Segment Design

- **35” Mirror Blanks to be cast in pyrex for 15 X cost savings**
- **ROC control relaxes radius matching tolerance for significant fab cost savings**
- **Design optimized from initial to current profile**
- **ROC control induced WFE decreased from 225 to 32 nm**
- **Mirror profile minimizes thermal equilibration time**
- **Further optimization to 20 nm WFE over ROC control range possible**

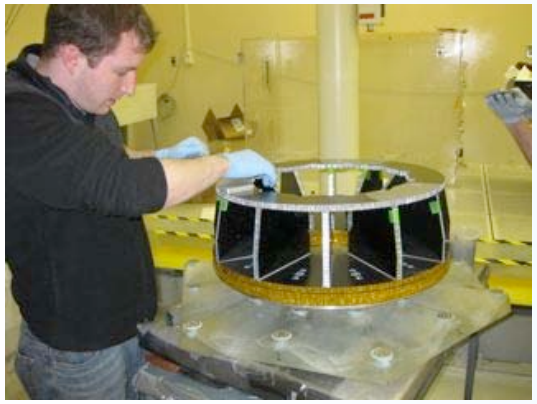


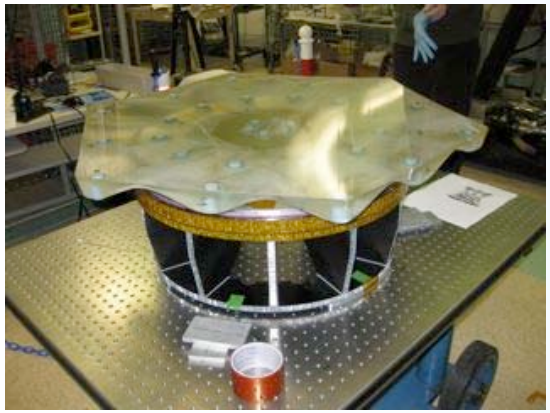




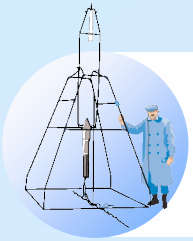
Accomplishments

SPOT Segment 1 Pathfinder Assembly

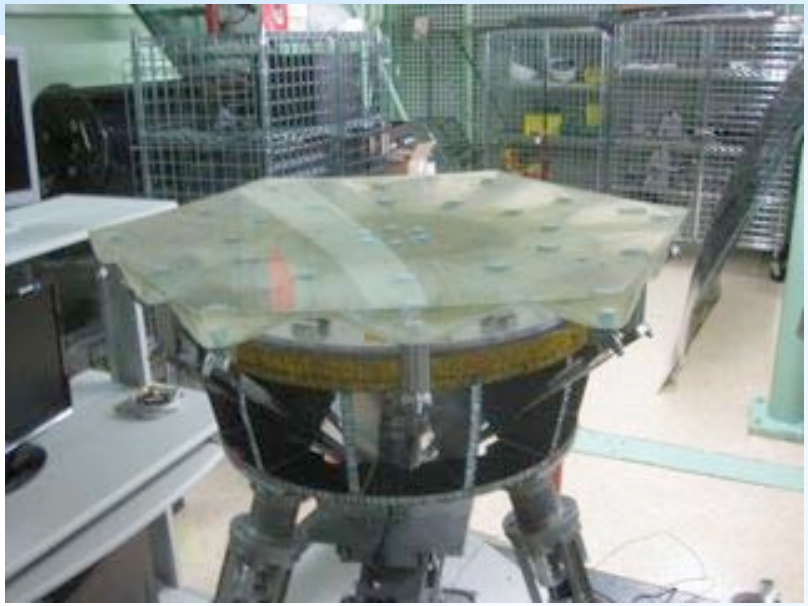




- **SPOT Mirror Composite Pathfinder Support Structure Assembled**
- **SPOT Segment 1 Figure Measured on Support Structure**
- **Segment 1 assembled to tip/tilt piston assembly and measured for MRF Hit Map for figuring**
- **Check of figure change when Radius of Curvature Actuator integrated**
  - **As predicted effect of 20 lb actuator assembly is primarily focus change**

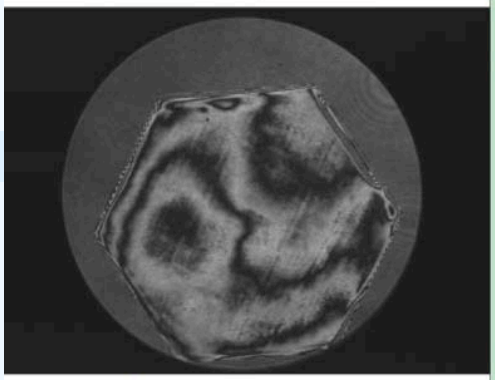


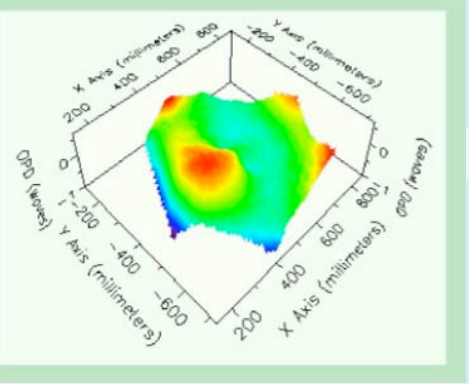
SPOT Segment 1 ROC Adjustment



- **SPOT Segment 1 radius adjusted by bending mirror**
- **This allows radius matching of segments in test bed**
- **Pathfinder segment had initial aberrations that limited performance**

FILE: POST SET 4 AVG	IntelliWave Report Sheet
Interferogram #1	Surface Map





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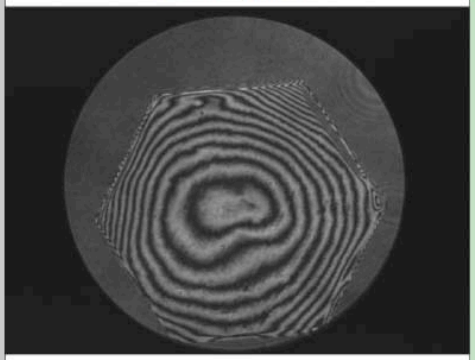
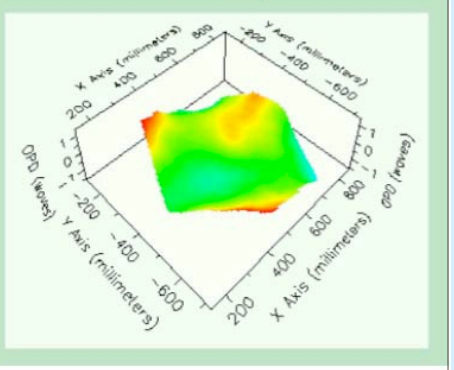
4) Focus:	-0.0778	-107374176.0000	-107374176.0000	-	
5) X Astig:	-0.1394	-107374176.0000	-107374176.0000	-	
6) Y Astig:	0.1742	-107374176.0000	-107374176.0000	-	
7) X Coma:	0.5858	-107374176.0000	-107374176.0000	-	
8) Y Coma:	0.0742	-107374176.0000	-107374176.0000	-	
9) Spherical:	-0.0658	-107374176.0000	-107374176.0000	-	

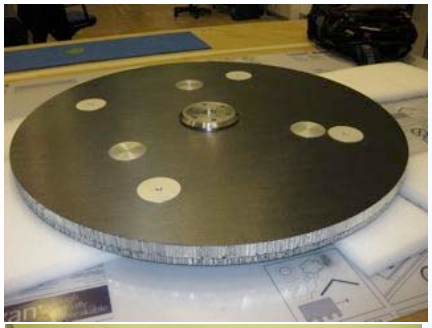
OPD Statistics:	Value	(waves)		
PV 98.00%.....	1.0814			
RMS.....	0.2233	0.0000	0.0000	-
Date(measured):	Wed Nov 18 14:39:44 2009			

	1	2
1	ILE: SET 4 NEG 1500K STEPS POST TWEAK AV	IntelliWave Report Sheet
2		
3	Interferogram #1	Surface Map
4		
Note	, CameraRes = 0.0000, CameraRes = 0.0000	

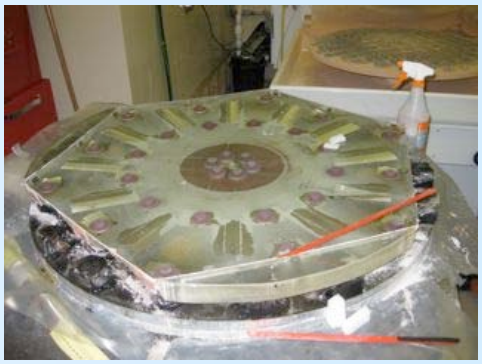
6	4) Focus:	0.0029	-107374176.0000	-107374176.0000	R	OPD Statistics: Value (waves)
7	5) X Astig:	0.0029	-107374176.0000	-107374176.0000	-	PV 98.00%..... 1.6840
8	6) Y Astig:	-0.1050	-107374176.0000	-107374176.0000	-	RMS..... 0.3016 0.0000 0.0000 -
9	7) X Coma:	-0.4901	-107374176.0000	-107374176.0000	-	
10	8) Y Coma:	0.2514	-107374176.0000	-107374176.0000	-	Date(measured): Wed Nov 18 14:33:53 2009
11	9) Spherical:	-0.0417	-107374176.0000	-107374176.0000	-	

Accomplishments - Meter Class Optics at GSFC

Segment 2 Grinding and polishing



- **Bldg 7 Room 7 Reconfigured for Polishing Lab**
- **Composite Polishing Fixture fabricated (>10 x lighter than previous fixture)**
- **Pitch pucks installed on polishing fixture**
- **Mirror polishing on new Strasbaugh 6-O machine**
- **Mirror being inspected**
- **Segment 2 surround removal**
- **4 Fabrication and Test related NTR's generated**



Accomplishments

Segment 2 Installed on Generation 2 Box

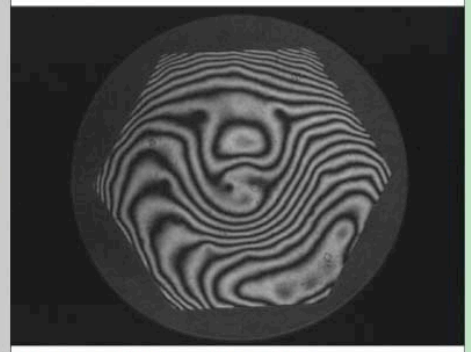
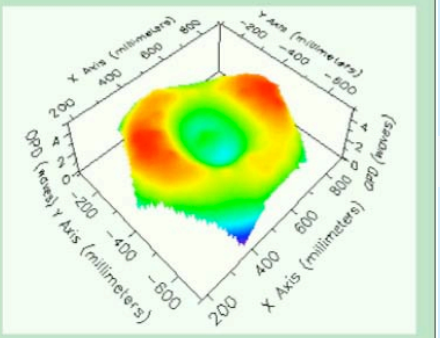
- **Fabricated in Composites Shop Bld 5**
- **Designed by J. Budinoff/540**
- **10-20x stiffer than Gen1**
- **Flexure interface**

- **Segment 2 Mounted**
- **Mirror fab 10x faster than Segment 1**
- **Mounted Figure 4 x better**
- **Next step final figuring at QED Technologies with MRF**

SPOT Segment 2

- **Better initial figure at GSFC**
- **Lower Mounting Error**
- **Optimized MRF Process at QED**

Segment 2 Pre MRF1

	1	2
1	FILE: 3_17	Wave Report Sheet
2		
3	Interferogram #1	Surface Map
4		
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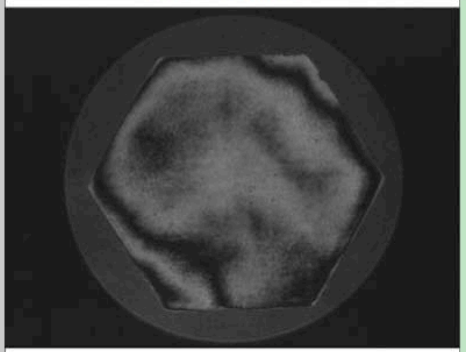
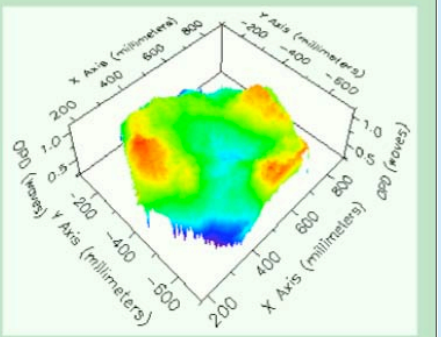
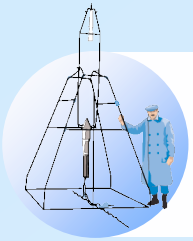
6	Date(measured): Thu Mar 18 17:20:21 2010				OPD Statistics:	Value	Min	Max (waves)
7					PV.....	4.9911		
8	4) Focus:	-0.7409	0.0000	0.0000 Removed	RMS.....	0.7546	0.0000	0.0000 -
9	5) X Astig:	0.9883	0.0000	0.0000 -				
10	6) Y Astig:	0.8883	0.0000	0.0000 -				
11	7) X Coma:	0.3086	0.0000	0.0000 -				
12	8) Y Coma:	0.2403	0.0000	0.0000 -				
13	9) Spherical:	-1.6143	0.0000	0.0000 -				

Segment 2 Post MRF2

	1	2
1	: 5_27 SEG2 MRF2 F	Wave Report Sheet
2		
3	Interferogram #1	Surface Map
4		
Note	, CameraRes = 0.0000, CameraRes = 0.0000	

6	Date(measured): Thu May 27 13:57:40 2010				OPD Statistics:	Value	Min	Max (waves)
7					PV.....	1.2185		
8	4) Focus:	-0.0592	0.0000	0.0000 Removed	RMS.....	0.1372	0.0000	0.0000 -
9	5) X Astig:	0.0923	0.0000	0.0000 -				
10	6) Y Astig:	0.1719	0.0000	0.0000 -				
11	7) X Coma:	0.0393	0.0000	0.0000 -				
12	8) Y Coma:	0.1290	0.0000	0.0000 -				
13	9) Spherical:	-0.1414	0.0000	0.0000 -				



Next Steps

- Segment 2 gets an additional 1 MRF at QED
- Segment 3 figuring at GSFC is within .05% of nominal radius (need to get to .025%)
  - Delivery to QED for at least 2 MRF runs
- Segments 1 and 2 will begin phasing experiments after delivery of Segment 2 from QED
  - Integration of tip/tilt piston control with WFSC module
  - Completion of WFSC module (WISH)
  - Completion of WFSC algorithms